Using probabilistic methods in water scarcity assessments: A first step towards a water scarcity risk assessment framework

Ted Veldkamp[1], Yoshihide Wada[2,3,4], Jeroen Aerts[1], Philip Ward[1] (E-mail: ted.veldkamp@vu.nl)

[1]Institute for Environmental Studies (IVM), VU Amsterdam, Netherlands, [2] Center for Climate Systems Research, Columbia University, USA, [3]NASA Goddard Institute for Space Studies, New York, USA, [4]Department of Physical Geography, Utrecht University, Netherlands

Introduction

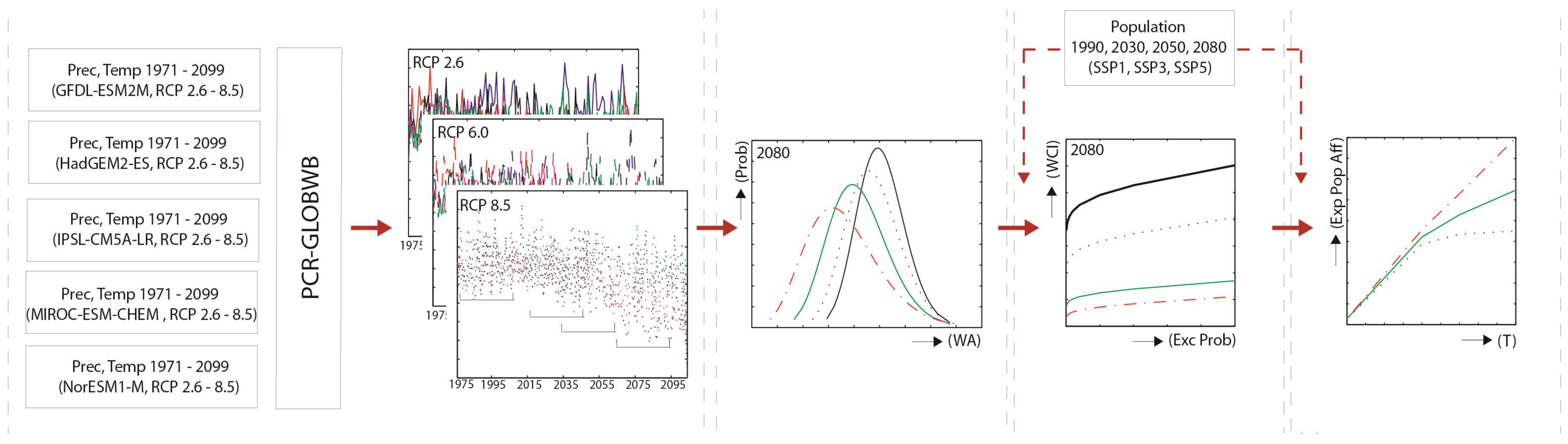
Water scarcity -driven by climate change, climate variability, and socioeconomic developments- is recognized as one of the most important global risks, both in terms of likelihood and impact. Whilst a wide range of studies have assessed the role of long term climate change and socioeconomic trends on global water scarcity, the impact of variability is less well understood. Moreover, the interactions between different forcing mechanisms, and their combined effect on changes in water scarcity conditions, are often neglected.

Therefore, we provide a first step towards a framework for global water scarcity risk assessments, applying probabilistic methods to estimate water scarcity risks for different return periods under current and future conditions while using multiple climate and socioeconomic scenarios.

Research approach

We carried out the research as follows:

1. Simulated yearly water availability (WA) for 1971 – 2099 using PCR-GLOBWB (0.5° x 0.5°) under RCP 2.6 - 8.5
2. Used a Gamma distribution to fit probability density functions to yearly WA per water province (Fig. 1)
3. Estimated WA per return period (1yr - 1000yr) under current, 2030, 2050, and 2080 conditions
4. Calculated for each return period water scarcity (Water Crowding Index) for the storylines: Sustainability (RCP2.6 – SSP1), Fragmented World (RCP6.0 – SSP3), and Fossil-Fuel Based Developments (RCP8.5 – SSP5)
5. Assessed the Expected Annual Exposed Population (EA-EP) to water scarcity events (WCI ≤1700) for each storyline, under current and future conditions
6. Evaluated the impact of climate change, climate variability and socioeconomic developments on the severity and impact of water scarcity events



Covering mean and variance in probability distributions

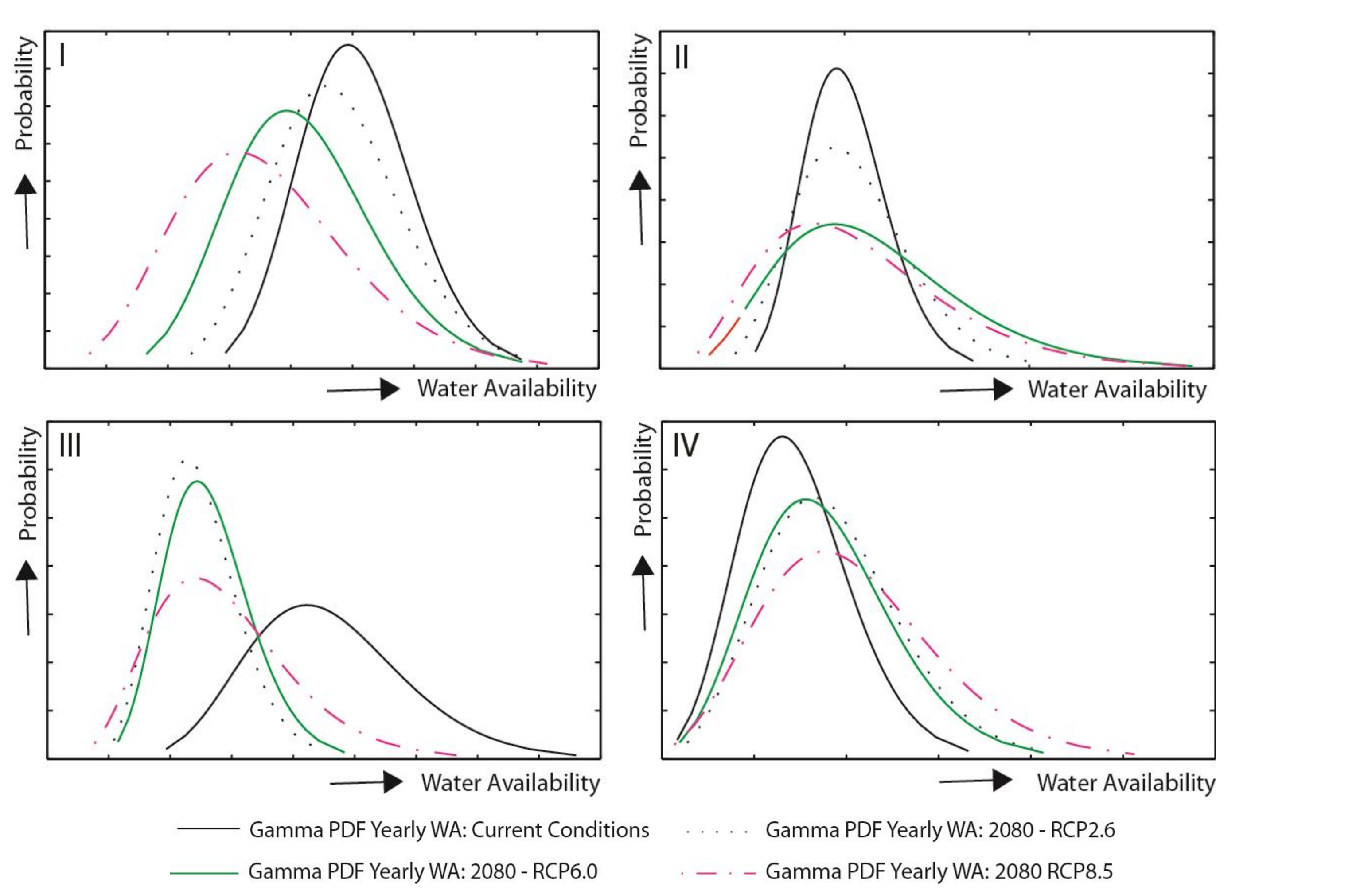


Fig. 1: Changes in shape of the probability distribution function (Gamma-function) describing the variation in yearly water availability under RCP2.6-8.5 in 2080 (colored lines) compared to the current conditions (black line) for a selection of basins. Looking at the location and shape of the probability distribution functions we can distinguish: (I) a decrease in mean water availability + increase in variability; (II) a constant mean water availability + increase in variability; (III) a decrease in mean water availability + decrease in variability; (IV) and increase in mean water availability + increase in variability. Although not depicted in this figurative example, other combinations of in-/decreasing means with in-/decreasing variability could also occur.

Probability and exposure to water scarcity events

Global scale water scarcity risk increases towards 2080 under all storylines, both in absolute and relative sense (Fig. 2). The water scarcity risk values found at the global scale are, however, not evenly distributed over the different world regions, with the highest relative EA-EP in Northern Africa (85.2% under SL: Fragmented World), and the lowest relative risk estimates in the Middle East (18.8% under SL Sustainability). GCM spread increases from global to regional scale, especially for the regions Australia & the Pacific, the Caribbean, Northern Africa, and Northern America

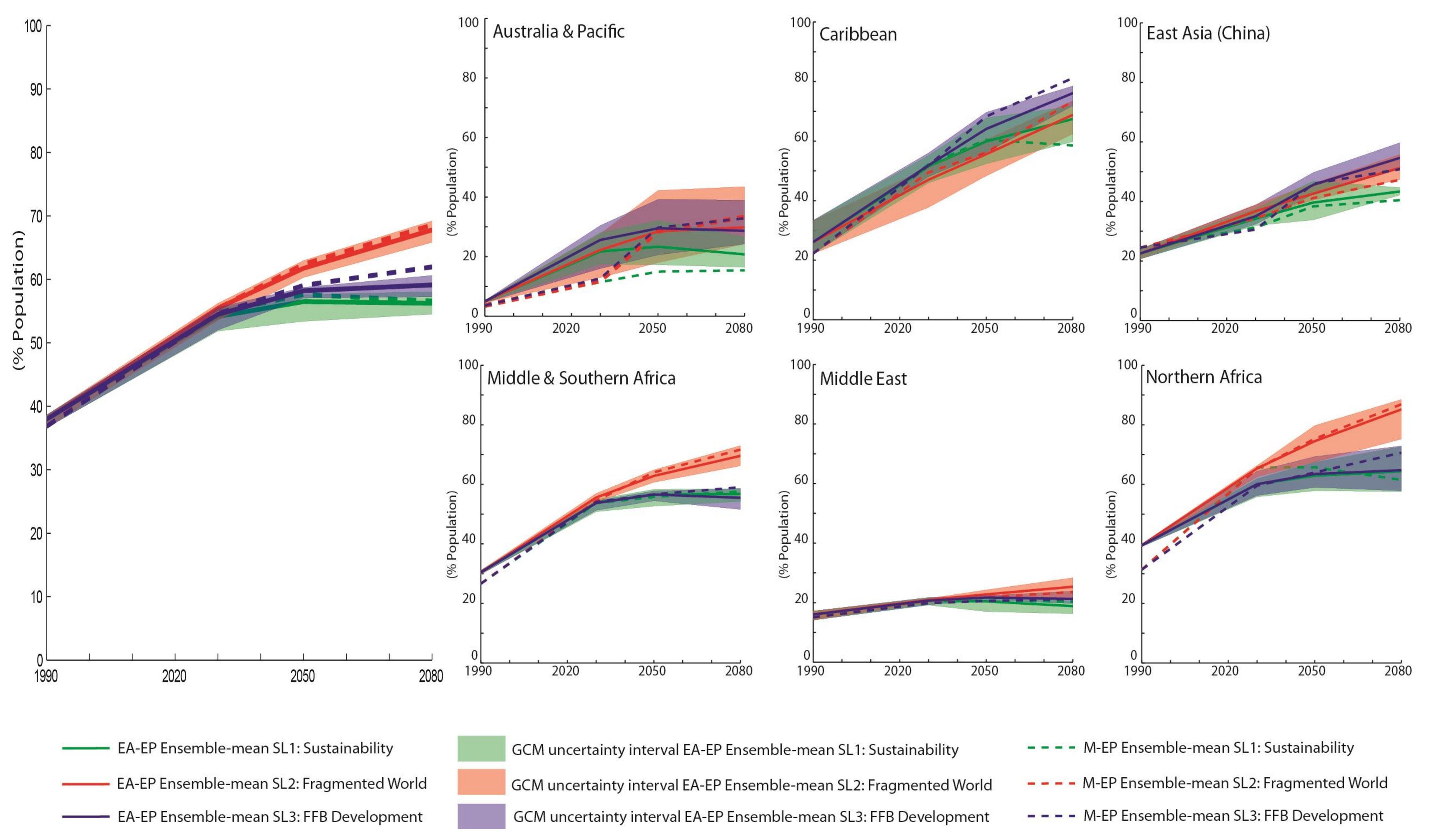


Fig. 2: Development of the exposure to water scarcity events at the global and regional scale. The colored lines show the development in Expected Annual Exposed Population (EA-EP) using a probabilistic water scarcity assessment approach. GCM uncertainty is expressed here by means of the shaded areas around these lines. The dashed lines show the development in Mean Exposed Population (M-EP) using 30-year mean water availability estimates.

When looking at the contribution of different driving forces to changing risk levels at the global scale we find that the factor socioeconomic developments is the largest attributor, irrespectively of the storyline and time-slice studied. Zooming in at the different world regions, we find variations in both the absolute and relative attribution to changing risk levels under the different storylines and time-slices, although socioeconomic developments remains to be the most dominant driving force in all cases. The spatial distribution of the largest drivers of change in EA-EP towards 2080 under the storylines Fragmented World and FFB Developments (Fig. 3) shows once more that water scarcity is not solely a climate change problem but merely an issue that constitutes from the developments in both the supply and demand of fresh water resources.

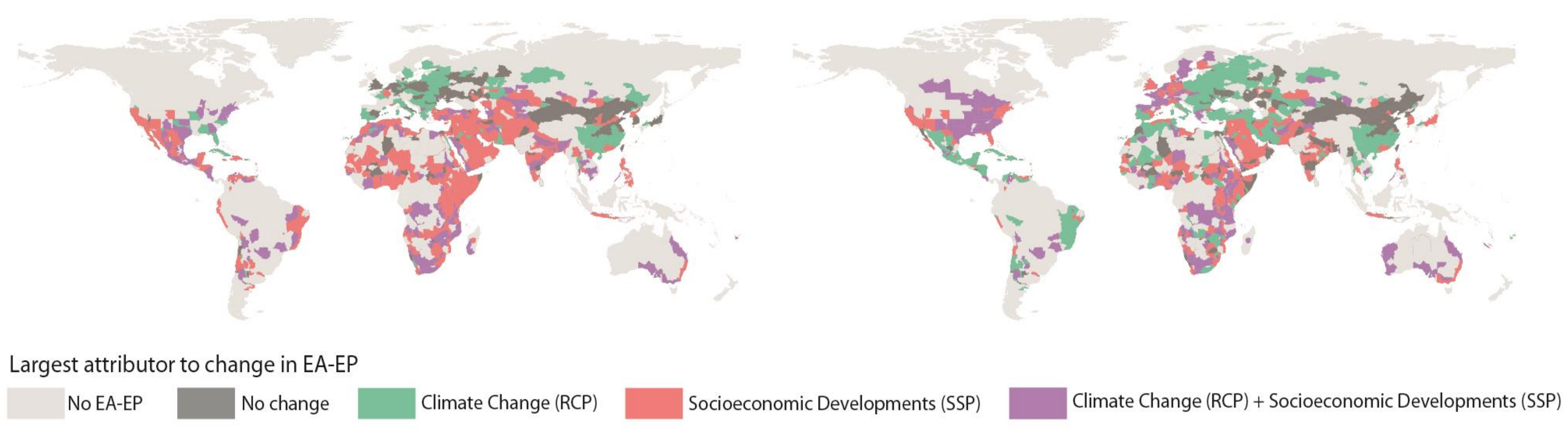


Fig. 3: Regional scale variation in the attribution to changes in risk (EA-EP) in 2080 compared to the current conditions under (a) storyline Fragmented World, and (b) storyline Fossil Fuel Based Development. Figures (a) and (b) show per water province the largest contributor to the expected change in risk: Climate Change (green), Socioeconomic Developments (red), or a combination of both (purple).

Conclusions and outlook

Preliminary results show the opportunities for a water scarcity risk framework to cover, illustrate and evaluate by means of probabilistic methods the impact of climate change, climate variability and socioeconomic developments, as well as their interaction effects, on current and future water scarcity conditions and their associated impacts at global and regional scales. Future research should focus on the incorporation of inter-basin interactions and the coupling between SSP and RCP scenarios in water availability estimates.

IVM Institute for Environmental Studies
VU Amsterdam
De Boelelaan 1087
1081 HV Amsterdam